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Demand for improved fish feed in the presence of a subsidy: a double hurdle application in Kenya

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Abstract

Fish farming households' demand for improved fish feed from the private market in Kenya is potentially influenced by the government's feed subsidy program. This article applies the double-hurdle model to a cross-section of fish farms to analyze demand for improved fish feed from private markets, and whether the government feed subsidy program has an effect on private demand for improved feed. The results indicate that households' decisions to participate in the improved feed market are affected by the quantity of improved feed received from the government. Once the participation decision has been made, we find evidence of *crowding-in* of the private improved feed sector; that is, the government's allocations of subsidized feed appear to increase private sector demand. In addition, the price of improved feed negatively affects the quantity purchased as expected. Education, extension contacts, and ease of marketing matured fish increase household propensity to purchase improved feed commercially. Policies that help reduce the price of improved feed such as reduction in tariffs on imported feeds and feed ingredients will foster demand for the feed, as will policies that facilitate marketing of fish at reasonable prices by households.

JEL classifications: C34, Q12, Q13, Q18, Q22

Keyword: Improved feed; Feed demand; Kenya; Subsidized feed; Economic Stimulus Program; Double-hurdle model; Market participation; Fish farming households; Aquaculture

1. Introduction

Agricultural input subsidy programs in Africa have focused mainly on crop production inputs—fertilizer and improved seed varieties. Consequently, empirical analyses of agricultural input demand in the presence of respective input subsidies have concentrated on fertilizer (Jayne et al., 2013; Liverpool-Tasie, 2014; Ricker-Gilbert et al., 2011; Xu et al., 2009), and improved seed varieties (Mason and Ricker-Gilbert, 2013; Smale et al., 2014). Input subsidy programs have both economic and social objectives, targeting poor smallholder households. In some cases, these programs have been designed to enhance input use and private market participation, thereby increasing production, and reducing poverty. Recent empirical analyses of the impact of government input subsidy programs, however, reveal conflicting results. Some studies have found government input subsidy programs to *crowd-out* the private sector (Jayne et al., 2013; Mason and Ricker-Gilbert, 2013; Ricker-Gilbert et al., 2011; Xu et al., 2009). Other studies have found that agricultural input subsidies *crowd-in* the private sector, such that farmers' purchase of the targeted input from the market is enhanced by the subsidy (Liverpool-Tasie, 2014; Xu et al., 2009). The *crowding-out* or *crowding-in* effect of an input subsidy program depends partly on how active the private sector is in a particular area. The implication is that within a country or region, an input subsidy program may have both negative and positive effects on farmers' private market participation (Xu et al., 2009).[1]

There is little or no evidence of empirical work on the impact of aquaculture input subsidy programs in Africa. Kenya has, however, implemented an aquaculture-specific input subsidy program in recent years. In 2009, as part of Kenya's Economic Stimulus Program (ESP), the government dedicated about Kshs 1.12 billion (US$ 15 million) to fish farming (we refer to the aquaculture component of the ESP as "aquaculture ESP"). The aquaculture ESP focused on pond construction, fish feeds and fingerlings supply, as well as building producer capacity

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Data Appendix Available Online

A data appendix to replicate main results is available in the online version of this article.

[1] Xu et al. conducted two sets of analyses depending on the level of activity of the fertilizer private sector in a given area. They found evidence of *crowding-out* in areas where the private sector is relatively active and incomes are high. On the other hand, fertilizer subsidies increase household demand for fertilizer in areas where the private sector is relatively inactive and households are poor.

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(Government of Kenya, 2009). The aquaculture sector in Kenya has seen a tremendous positive shift in production following the implementation of the program. Prior to the implementation of the program, Kenya's farmed fish production increased from 1,012 MT in 2003 to 4,895 MT in 2009. Farmed fish production rose from the 2009 figure to about 21,487 MT in 2012 (State Department of Fisheries, 2012). Likewise, the value of aquaculture production increased from Kshs 1.041 billion in 2009 to about Kshs 4.634 billion (US$56 million) in 2012. Thus, Kenya is among the sub-Saharan African nations making rapid progress toward becoming major aquaculture producers in the subregion—alongside Ghana, Nigeria, Uganda, and Zambia (FAO, 2012).

The ESP on aquaculture sought to raise household interest in aquaculture and also boost adoption of improved aquaculture technologies, such as commercially formulated pelleted floating feed and quality fingerlings. The presence of a feed subsidy program in Kenya implies that fish farming households can obtain improved feeds from two major sources—purchases from commercial markets and the government feed subsidy program (Xu et al., 2009). Thus, households' decisions to purchase improved feed from the private retail market and the quantity actually purchased are explained by household sociodemographic and institutional considerations, and the amount of subsidized feed they receive from the government.

Here, we examine the factors that influence fish farming households' demand for improved feed in the presence of the subsidy program in Kenya. We test the hypothesis that the feed subsidy program limits a household's market participation decision, and the intensity of demand for improved feed. Several studies examine the impact of government input subsidy programs on fertilizer and improved seed demand in Africa (Mason and Ricker-Gilbert, 2013; Ricker-Gilbert et al., 2011; Xu et al., 2009), but to the best of our knowledge, there is no such study on the aquaculture sector in Kenya. Similarly, there is much literature on agricultural technology adoption (Adesina and Zinnah, 1993; Amare et al., 2012; Feder and Umali, 1993), but these studies are limited for research on improved aquaculture technologies in Africa (Dey et al., 2010), especially Kenya.

2. Modeling framework and estimation techniques

2.1. Conceptual framework

Feed is the main input in a fish farming enterprise, estimated to constitute 30–80% of total variable cost of production depending on the farming system (Cocker, 2014). Two categories of feeds are used for fish farming in Kenya—improved and traditional.[2] These feeds come from different sources, and fish farming households use either one type or a combination.

In a given production year where the government subsidy program is in place, the total quantity of improved feed used by the household is the sum of subsidized feed and that purchased commercially. Given that allocation of subsidized feed is the government's decision rather than the household, we focus on the factors that determine the quantity of improved feed purchased commercially, and how the quantity of subsidized feed acquired influences demand for improved feed.

In Kenya, as in other developing countries where markets are imperfect, sociodemographic factors are likely to affect resource allocation, such that household consumption and production decisions are nonseparable (de Janvry and Sadoulet, 2006; Singh et al., 1986).

Following Singh et al. (1986), household demand for improved feed in Kenya is specified as:

$$C_{pf} = f\left(C_{sf}, \boldsymbol{P}, \boldsymbol{Q}, \boldsymbol{K}\right), \tag{1}$$

where C_{pf} is the quantity of improved feed purchased commercially in 2013, C_{sf} is the quantity of subsidized feed received from the government in 2013, $\boldsymbol{P}$ is a vector of prices including the prices of improved and traditional feeds, and the expected price of Tilapia. $\boldsymbol{Q}$ is a vector of household characteristics, $\boldsymbol{K}$ is a vector of other aquaculture input demand determinants such as difficulty in fish marketing, ownership of water pumps, and source of pond water.

2.2. Control function (CF) approach: effect of subsidized feed on improved feed demand

As part of the aquaculture ESP, some households in the sample obtained improved feed from the government in the 2013 production year and years preceding that.[3]

Allocation of subsidized feed to households in Kenya, as in most public input subsidy distribution systems in Africa, is not random, but based on some unobservable factors. That is, access to subsidized feed is a government and/or extension agent's decision rather than the household's. In the demand model for improved feed, the quantity of government subsidized feed might be endogenous due to its possible correlation with unobservable determinants of improved feed demand. Estimating the demand model for improved feed without taking into account this potential endogeneity might bias the results, leading to inconsistent estimates and misleading policy conclusions. To control for this, we use the CF approach (Lewbel, 2004; Ricker-Gilbert et al., 2011; Smith and Blundell, 1986; Wooldridge, 2010, p. 90).

Estimating the CF requires an instrumental variable (IV). Theoretically, the selected IV should be correlated with the

[2] Improved feeds are nutritionally balanced with the required protein content. They are extruded to float, facilitate easy feeding, and reduce feed wastage. Improved feeds are dry and pelleted, with low feed conversion ratio of about 1.8 kg of feed per kilogram of fish weight gain (Isyagi et al., 2009 cited in Cocker, 2014). Traditional feeds do not have the same nutritional content and quality.

[3] The reference period in this article is the 2013 production year. Hence, we focus on subsidized feed received in 2013. Some households might have received subsidized feed in years preceding 2013, but not in 2013. These households are classified as nonrecipients. Thus, we consider the impact of 2013 subsidized feed acquired on household market participation and intensity of participation in 2013.

endogenous variable (in this case, subsidized feed) but uncorrelated with the error term in the structural equation. The major problem with any empirical econometric analysis involving IVs is finding a strong instrument. Here, we follow the approach of Ricker-Gilbert et al. (2011), using the number of years the household head has lived in the community as an instrument. The number of years that the household head has resided in the current location could influence the quantity of subsidized feed the household receives. Household heads who have resided longer in their current location might have political and social connections that boost their likelihood of receiving government subsidized feed as well as the quantity acquired, *ceteris paribus*. There is, however, little reason to believe that years of residing in the current location would influence unobservable factors in the structural feed demand model after controlling for observable covariates. The number of years lived in the current location might influence other demand determinants such as knowledge of where to obtain the feed, feed cost, transaction costs, and other relevant information pertaining to the decision to use the technology. We control for these variables, so that the instrument is exogenous in the structural model for improved feed.

The CF approach involves a number of stages. In the first stage, a model examining the determinants of subsidized feed acquired by the household is estimated. Because the decision of whether or not a household receives subsidized feed is solely that of the government (as represented by fisheries extension agents and/or local leaders), we model the determinants of subsidized feed allocation in a single stage where the dependent variable is the kilograms of subsidized feed, against observable covariates of the structural model, including the IV. Residuals from the first stage subsidized feed acquisition model are then used as a covariate in the second stage structural model. If the residual is significant in the second stage model, it implies that subsidized feed is correlated with the demand for improved feed, and therefore this correlation has to be taken into account when estimating the quantity of improved feed purchased by the household. If the quantity of subsidized feed is significant in the structural model after controlling for potential endogeneity, it will have two different implications depending on the sign. A positive sign indicates *crowding-in* such that government subsidized feed acquisition increases the quantity of improved feed purchased commercially. A negative effect implies *crowding-out*.

2.3. Model choice for improved feed demand: double-hurdle (DH) model

After correcting for potential endogeneity of subsidized feed, two categories of households are identified in Kenya with regards to the quantity of improved feed demand. Some households did not purchase any improved feed from the market, and therefore have an optimal demand of zero, while others had strictly positive optimal choice. The former have zero observed demand given current prices, transaction costs, and sociodemographic characteristics. In order to model demand for improved feed while taking account of these households, we employ a corner solution technique that treats zeros as the optimal choices rather than as unobserved values.

In the adoption literature, three modeling approaches have been employed to empirically analyze the intensity of adopting (or demanding) a new agricultural technology—the Tobit model, originally due to Tobin (1958); the DH model due to Cragg (1971); and the Heckman two-step procedure developed by Heckman (1979). The Heckman approach is used in situations where selection bias in data influences analysis, especially where the zeros are treated as unobserved values (Coady, 1995; Puhani, 2000; Ricker-Gilbert et al., 2011).

In situations where the decision to participate simultaneously involves the decision regarding the quantity purchased, the Tobit model is preferred (Adesina and Zinnah, 1993; Feder and Umali, 1993; Norris and Batie, 1987). The Tobit approach is a corner solution model where the zeros are observed and represent the optimal choices of nonparticipating households. The application of the Tobit model to the commercial demand for improved feed, however, requires a restrictive assumption—that the decision to purchase and the quantity actually purchased are determined by the same factors and in the same process (Coady, 1995; Ricker-Gilbert et al., 2011). The determinants of the quantity of subsidized feed received by the household are estimated using the Tobit model since the allocation and quantity allotted to a particular household are determined by the same set of factors by the government.

Given the shortcomings of the Tobit procedure as a corner solution model, a lognormal DH model is used in the current study to examine the demand for improved feed. Double hurdle models allow for factors influencing the household decision to purchase improved feed, and the quantity purchased to differ and be determined by different processes (Coady, 1995; Croppenstedt et al., 2003; Jayne et al., 2013; Mason and Ricker-Gilbert, 2013; Ricker-Gilbert et al., 2011). To the best of our knowledge, this study is the first to utilize a DH model to assess the impact of subsidies on improved fish feed demand in Kenya.

2.4. DH model specification and estimation technique

After controlling for the potential endogeneity resulting from government subsidized feed, we apply the lognormal DH model to improved feed demand. The decision to purchase improved feed is modeled by an indicator function based on the net profitability of use. Let π_c and π_0 be the expected profit from using and not using improved feed, respectively. The household purchases improved feed if $(\pi_c - \pi_0) > 0$.

The latent variable underlying household i's decision to purchase improved feed from the market M_i^*, is specified as:

$$M_i^* = \boldsymbol{\alpha}' \mathbf{Z_i} + e_i, \qquad (2)$$

so that the observed participation decision, M_i can be modeled as:

$$M_i = \begin{cases} 1 & \forall \quad M_i^* > 0 \\ 0 & \forall \quad M_i^* \leq 0 \end{cases}, \tag{3}$$

where $\boldsymbol{Z_i}$ is a vector of determinants of the decision to purchase including the quantity of subsidized feed and the reduced form residual; $\boldsymbol{\alpha}'$ is a vector of purchase parameters to be estimated; and e_i is a normally distributed error term with zero mean and constant variance.

Similarly, let the ith household's desired demand for improved feed C_i^*, be specified as:

$$C_i^* = \exp(\boldsymbol{\beta}' \boldsymbol{H}_i + \mu_i). \tag{4}$$

The observed demand, C_i, is then modeled as:

$$C_i = \begin{cases} C_i^* & \text{if } C_i^* > 0 \quad \text{and} \quad M_i = 1 \\ 0 & \text{otherwise} \end{cases}, \tag{5}$$

where $\boldsymbol{H_i}$ is a vector of demand factors, including the quantity of subsidized feed and the reduced form residual; $\boldsymbol{\beta}'$ is a vector of demand parameters to be estimated; and μ_i is the random error term which is log-normally distributed with zero mean and constant variance, δ.

The purchase and demand equations are assumed to be independent (Amare et al., 2012; Croppenstedt et al., 2003), and estimated using a maximum likelihood (ML). The log-likelihood equation is specified as follows:

$$\ln(L) = \left[1 - \Phi\left(\alpha' Z_i\right)\right] + ln\left[\Phi\left(\alpha' Z_i\right)\right] + \left\{\left(\phi\left[\ln(C_i) - \beta' H_i/\delta\right]\right) - \ln(\delta) - \ln(C_i)\right\}, \tag{6}$$

where $\phi(.)$ and $\Phi(.)$ are the normal probability density function and cummulative distribution function, respectively. The expected value of improved feed demand conditional on strictly positive purchases is:

$$E\ (C|H, C > 0) = \ exp(\beta' H_i + \delta^2/2). \tag{7}$$

We compute the average partial effects (APEs) of changes in explanatory variables on demand for strictly positive quantities of improved feed, evaluated at the ML estimates and the sample means of the regressors.

The first hurdle (3) is estimated as a Probit model (binary response), in which the dependent variable is one if the household participated in the market for improved feed, and zero otherwise. The second hurdle (5) is estimated using a truncated regression. The dependent variable in the second hurdle is the logarithm of the total quantity of improved feed purchased commercially.

3. Data and variable measurement

3.1. Data

This study uses cross-sectional data obtained through questionnaire administration to a sample of fish farming households in Kenya. The data were collected between January and April 2014, using a multistage sampling technique. In the first stage, the Western and Rift Valley regions were purposefully selected mainly due to the predominance of smallholder aquaculture operations and earthen pond utilization. Moreover, the differences in temperature across the two regions provide a good contrast (the Western region is warmer than the Rift Valley). We randomly selected six subcounties from each region. From these subcounties, a random sample of 198 fish farming households was drawn from the aquaculture population for interviews.[4] The district fisheries offices in Kenya keep a census list of fish farms for monitoring and policy-related interventions. The random sample of 198 farms comes from this list of aquaculture producers.

Questionnaires solicited information on sociodemographic characteristics of the household, institutional support for aquaculture operations (e.g., credit, extension, and market opportunities), farm level outputs and inputs, technology adoption and constraints, government program participation, household assets, etc. for the 2013 production year. The main fish species produced in the study area are Tilapia (*Oreochromis niloticus*) and Catfish (*Clarias gariepinus*), though the former is predominant. Tilapia tolerates relatively higher temperatures than Catfish, with water temperatures of 85–88°F optimal for Tilapia growth (Popma and Masser, 1999). Some households practice polyculture (combining Catfish and Tilapia in the same pond), to increase yield through diversification and to moderate Tilapia population in ponds.

3.2. Choice of explanatory variables

3.2.1. Feed and Tilapia prices

Given that some of the households did not buy improved feed from the market, there were some missing price information for improved feed. Likewise, observed prices were not available for households that did not use traditional feed. For households that purchased a particular feed type, the observed price was used—what they paid per kilogram of feed when they made the feed purchase decision. For those that did not participate in either market, the observed average district price was used. These prices are reported in Kenya Shillings per kilogram (Kshs/Kg). This approach was employed by Ricker-Gilbert et al. (2011) and Yi (2014).

[4] The sample size of 198 might seem small. Unlike agricultural enterprises practiced by a large number of rural households, aquaculture operations are not very prominent in rural Kenya. The sample, while modest, is representative of the aquaculture population in the Western and Rift Valley regions of Kenya. Therefore, any policy implications will be relevant for improved feed and aquaculture operations in these regions, and elsewhere in Kenya.

Table 1
Demand for different feed types across regions in Kenya

Region	Sample (#)	% of sample	Improved feed (kg)	Traditional feeds (kg)†	Improved and trad. feeds (kg)	% share of improved feed in total feed
Full sample						
All regions	198	100	142	330	472	30
Rift Valley	90	45	140	434	574	24
Western	108	55	144	243	387	37
Market participants						
All regions	93	47	252	202	454	55
Rift Valley	35	39	251	289	540	47
Western	58	54	252	151	403	63

[a]Traditional feeds include cotton cake, fish meal, corn meal, etc. either formulated or purchased by the household.
Source: Authors computation, based on 2014 fish farm household survey.

When households decide to purchase improved feed, the prices of Tilapia and Catfish are what was observed at that time. The observed price at the realization of fish output and sales might differ from what prevailed at the time when the input purchase decision was made. Thus, the household forms expectations of the price at harvest to inform the input choice decision. We employ the naive expectations approach where the lagged district price is used to predict harvest price for the household (Ricker-Gilbert et al., 2011; Yi, 2014). We adapt an approach by Yi (2014, p. 15) to generate output price for the household. In this framework, the lagged district price for the ith household is the average output price in the district excluding the particular household. Available district price data shows little variation in Tilapia and Catfish prices across a production cycle. Since Tilapia is the main species cultivated in the study area, we focus only on the price of Tilapia.

3.2.2. *Other explanatory variables*

Besides the prices of inputs and outputs, we include some household characteristics as well as institutional and farm level factors that are relevant to influence demand for improved feed. These factors include education and experience of the household head, social assets (e.g., membership in a fish farmers association), constraints to fish marketing, household asset holdings such as a water pump, and a reliable source of water for the pond. We use a regional dummy to control for locational availability of improved feed and other geographical differences. The choice of these variables is guided by the adoption and input market participation literature.

4. Summary statistics

Here, a market participant is defined as a household that purchased improved feed from the commercial market. There are some households that used both improved and traditional feeds, and therefore we do not restrict our definition to households that used solely improved feed. This definition, however, treats households who acquired subsidized feed from the government in the reference year but did not purchase any commercially as nonparticipants.

The distribution of demand for improved feed across regions is presented in Table 1. Table 1 indicates 47% participation in the sample, with a nonuniform spread across regions. The percentage of households participating in the market is higher in Western Kenya (54%) than in the Rift Valley region (39%). In addition, we observe a direct relationship between the percentage of households purchasing the feed and the quantity used on the farm. The share of improved feed in total feed usage is 30% for the full sample, but 55% among market participants. At the regional level, improved feed constitutes a greater proportion of total feed demand in the Western region than in the Rift Valley, irrespective of sample separation. This is consistent with the high participation rate and the intensive nature of aquaculture operations in the Western region.

In Table 2, we present characteristics of households based on the source of improved feed. As indicated, some households obtained improved feed from different sources, which warrants disaggregating the data to examine the characteristics of the different categories of households in terms of feed sources. Out of the 47% who purchased improved feed from the market (Table 1), approximately 30% did not receive government subsidized feed and therefore obtained their improved feed from the market (Table 2). In addition, 17% obtained subsidized feed and some portion of improved feed from the market. Table 2 also indicates that 9% of households used improved feed exclusively from the government subsidy program. Thus, 26% of the households accessed the subsidized feed. The data suggest that, on average, households who acquired subsidized feed have resided in their current locations longer than those that purchased solely from the retail market, a variable likely to enhance lobbying for subsidized feed. Moreover, households that participated either partially or fully in the commercial improved feed market are closer to retail markets than their counterparts.

The definitions of variables used in the analysis and their descriptive statistics are presented in Table 3. Table 3 indicates that household heads in general have spent about 11 years in school, which is near completion of secondary school. High

Table 2
Source of improved feed by household characteristics

	Household improved feed source			
	Government ESP only	Commercial market only	Both sources	Not using improved feed
Share of households in total sample (%)	9	30	17	44
Household feed from government (Kg)	261.3	0.0	127.1	0.0
Household feed from market (Kg)	0.0	224.9	173.8	0.0
Fish farm size (acres)	0.15	0.17	0.25	0.12
Length of Stay in community (years)	30.9	29.6	35.3	31.7
Distance to nearest main market (km)	9.4	9.7	7.4	9.4
Distance to extension office (km)	11.8	10.6	12.3	10.7
Distance to nearest AquaShop (km)	19.3	12.2	13.1	15.8

Source: Authors computation, based on 2014 fish farm household survey.

Table 3
Definition of variables and descriptive statistics

Variable	Description	Sample mean	Standard deviation
Dependent variables			
Improved feed quantity	Quantity of improved feed purchased from the market (Kg)	97.13	188.59
Market participation	1 if the household participation in improved feed market	0.47	0.50
Independent variables			
Years resided	Number of years that the household head has live in community	31.58	17.24
Subsidized feed	1 if household received subsidized feed, and 0 otherwise	0.26	0.44
Subsidy quantity	Quantity of subsidized feed received (Kg)	44.94	105.95
Subsidized feed share	Share of subsidized feed in total improved feed used (%)	17.73	33.50
Education	Years of education of household head	11.40	3.88
Household size	Number of people in the household	6.85	2.88
Experience	Household head years of fish farming experience	4.38	3.65
Agricultural land	Total household farm land in acres	4.90	6.82
Fish farm size	Total fish farm land in acres	0.16	0.18
Cattle	1 if the household owns Cattle, and 0 otherwise	0.87	0.33
Water pump	1 if household owns water pump, and 0 otherwise	0.19	0.39
Water source	1 if source of pond water is river, and 0 otherwise	0.58	0.49
Extension access	1 if household had access to fisheries officer, and 0 otherwise	0.60	0.49
Extension contact	Number of extension contacts received	2.23	2.94
Fish farmers association	1 if head is a member of fish farmers association, and 0 otherwise	0.68	0.47
Credit	1 if household accessed credit specifically for fish farming, and 0 otherwise	0.11	0.32
Distance AquaShop	Distance to AquaShop (Km)	14.57	13.59
Marketing constraint	1 if household faces difficulty marketing fish in the past, and 0 otherwise	0.44	0.50
Tilapia price	Observed price of Tilapia (Kshs/Kg)	208.82	37.41
Improved feed price	Price of improved feed (Kshs/Kg)	72.83	15.33
Traditional feed price	Price of other made feeds (Kshs/Kg)	46.22	15.16

Source: Authors computation, based on 2014 fish farm household survey.

levels of education might explain potential correlation between education and adoption of improved feed among fish farming households in the Western and Rift Valley regions of Kenya. Moreover, household heads have on average 4.38 years of fish farming experience, which has implications for market participation and the extent thereof in Kenya. The variation in experience, captured by the standard deviation of 3.65 years, indicates that there is longevity of aquaculture operations in the regions as new entrants continue to enter the industry. This is also vital for the sustainability of the sector and possible adoption of technologies such as improved feed.

The average fish farm size (fish pond) is 0.16 acres, which is about 468 square meters. Pond surface areas were obtained in square meters, which were converted into acres to ease interpretation of the results. As part of the aquaculture ESP, the government constructed 300 m^2 ponds for households participating in the program. Households own about five acres of agricultural lands on average, indicating potential for expanding areas under fish farming, and may be candidates for possible adoption of improved feed.

Access to support services for aquaculture was limited in the study area. Only 11% of households accessed credit for fish farming purposes. Given the rising cost of improved feed, the availability of credit will potentially foster participation in the improved feed market and the extent thereof after controlling for other observable covariates. The average distance from fish

Table 4
Tobit result of factors affecting quantity of subsidized feed received

Dept. var: Quantity of feed (Kg)	Average partial effect	P-value
Independent variables		
Years resided	0.96**	0.03
Household size	4.07*	0.09
Education	3.85**	0.03
Experience	−1.70	0.40
Fish farm size	63.06**	0.05
Agricultural land	−0.25	0.80
Cattle	−27.36	0.16
Extension contacts	1.54	0.33
Credit	17.64	0.35
Fish farmers association	14.88	0.30
Distance AquaShop	0.35	0.51
Marketing Constraint	−34.55**	0.02
Expected price of Tilapia	−0.30	0.18
Observed price of improved feed	0.44	0.34
Observed price of traditional feed	0.49	0.21
Water source	−22.81*	0.08
Water pump	10.25	0.64
Western region dummy	−11.86	0.49

*, **, and *** represent significance at 10%, 5%, and 1%, respectively.

farm to an AquaShop, where improved fish feed is sold, is about 15 km—a variable reflecting the transaction cost of purchasing improved feed. Thus, households might prefer to use traditional feeds if improved feed is available only in a distant location.

5. Results and discussion

5.1. Factors influencing household acquisition of subsidized feed

Table 4 presents the reduced form Tobit model results for factors determining the quantity of subsidized feed acquired by households.[5] The variable of interest in this model is the number of years that the household head has resided in the current community (the IV to correct for potential endogeneity of subsidized feed in the structural demand model). This variable is positive and significant at the 5% level. The coefficient indicates that an additional year of residence in the community by the household head increases the household's subsidized feed acquisition by 0.96 kg, *ceteris paribus*. Given that the Tobit model is a nonlinear corner solution model, it is difficult to test for the strength of years lived in the community as an instrument. In this case, we follow Ricker-Gilbert et al. (2011) and Liverpool-Tasie (2014) to use the P-value and the estimate of the correlation between the IV and the endogenous variable to examine the exogeneity of the instrument in the structural model. With a P-value of 0.030, the IV is partially correlated with the endogenous variable of government subsidized feed in the structural improved feed demand model (Wooldridge, 2010, p. 90). It is, however, uncorrelated with the other unobservables in the structural model.[6] The correlation of the instrument with the endogenous variable and the fact that it is exogenous in the structural model makes it an ideal instrument to use in the structural model. In addition, the longer the household head has stayed in the current community, the more likely he/she will be socially and politically connected. With strong sociopolitical connections, the household will be able to lobby for subsidized feed, but the sociopolitical position of the household should not influence the quantity of improved feed purchased commercially.

The household head's years of education, household size, fish farm size, difficulty in marketing matured fish in the past, and source of pond water also influence how much subsidized feed a household receives from the government. Households with difficulty in marketing matured fish receive less subsidized feed. Household heads who have spent more years in school and operate larger fish farms receive larger quantities of subsidized feed than those otherwise.

5.2. Factors affecting demand for improved feed

The predicted generalized residual from the reduced form Tobit equation is used as an additional covariate in the structural participation and demand models. Table 5 presents the ML estimation results of the DH model for factors influencing households' demand for improved feed after controlling for potential endogeneity. Hurdle 1 contains the determinants of the decision to purchase while hurdle 2 shows the factors affecting the level of demand. The coefficients representing the marginal effects are evaluated at the means of each covariate. The marginal effects in the purchase decision represent the probability of improved feed market participation for changes in corresponding explanatory variables. For the demand model in hurdle 2, the marginal effects indicate the conditional expectation of improved feed demand as respective variables change (for dummy variables, change implies switching from zero to one). The ML estimation results were obtained in Stata 13 using the *probit* and *truncreg* commands for participation and demand, respectively. The marginal effects were estimated using the *margins* commands in Stata (details are found in Burke, 2009).

The reduced form residual is significant in both the purchase decision and demand models, indicating the endogeneity of subsidized feed in the structural model. Thus, failing to correct for this endogeneity would result in biased, inconsistent estimates.

Correcting for potential endogeneity, the analysis reveals a negative relationship between a household's decision to participate in the market and the quantity of subsidized feed received.

[5] The *tobit* command was used to estimate the Tobit model in Stata 13. APEs were estimated using the *margins* command.

[6] The correlation between quantity purchased from the market and the IV is −0.0020. In addition, estimating the structural demand model with the IV as a covariate shows an insignificant coefficient. These, and results from Table 4, justify that the IV is partially correlated with the subsidized feed, but uncorrelated with the quantity purchased commercially.

Table 5
Factors influencing household demand for improved feed in Kenya: double-hurdle model

	Hurdle 1		Hurdle 2		
	Participation in improved feed market (Probit)		Demand model (truncated regression)		
Independent variables	APE†	*P*-value	APE	*P*-value	% Change in APE
Quantity of subsidized feed	−0.002***	0.005	0.009***	0.000	0.90
Generalized Residual	0.301***	0.001	−1.199***	0.000	−119.9
Household size	0.010	0.428	−0.030	0.460	−3.00
Education	0.022**	0.017	−0.003	0.906	−0.30
Experience	0.004	0.655	0.039*	0.053	3.90
Fish farm land	0.698***	0.009	0.074	0.837	7.40
Agricultural land	0.000	0.93	0.018*	0.100	1.80
Cattle	−0.274***	0.008	−0.204	0.389	−18.49
Extension contacts	0.038***	0.003	−0.018	0.437	−1.80
Credit	0.110	0.272	−0.255	0.467	−22.52
Fish farmers association	−0.039	0.582	0.190	0.352	20.97
Distance AquaShop	−0.002	0.302	−0.011	0.158	−1.10
Marketing constraint	−0.247***	0.001	0.460**	0.012	58.34
Expected price of Tilapia	0.001	0.491	0.004*	0.066	0.40
Observed price of improved feed	−0.002	0.367	−0.021***	0.001	−2.10
Observed price of traditional feed	0.002	0.382	0.009	0.235	0.90
Water source	−0.024	0.731	0.285	0.143	32.94
Water pump	0.041	0.668	0.487*	0.060	62.67
Western region	0.057	0.537	0.519*	0.064	68.00

*, **, and *** represent significance at 10%, 5%, and 1%, respectively.
†APE denotes average partial effect.

Each kilogram of subsidized feed received by the household decreases their propensity to buy improved feed by 0.2 percentage points. Households receiving subsidized feed from the government may not need to purchase more from the market. This result is consistent with Xu et al. (2009) in Zambia; Ricker-Gilbert et al. (2011) in Malawi; and Liverpool-Tasie (2014) in Kano State, Nigeria.

In addition, a household's decision to purchase improved feed is influenced by the head's education, fish farm size, extension contact, difficulty in marketing matured fish, and ownership of cattle. Each additional year of education increases the probability of purchase by about 2 percentage points. Increased land in fish farming raises the likelihood of purchasing improved feed from the market, as does regular contact with extension agents. Households that experience difficulty marketing their matured fish are less likely to participate in the market. Finally, ownership of cattle decreases the likelihood of purchasing improved feed from the market.

After controlling for endogeneity of government subsidized feed and holding other factors constant, each kilogram of subsidized feed acquired by the household increases the quantity of improved feed purchased by about 0.90 percentage points. This indicates that government subsidized feed *crowds-in* private sector activities for improved feed. The coefficient is small, reflecting the modest quantity of subsidized feed received by households in the 2013 production year (government subsidized feed constitutes about 18% of improved feed use in the sample—see Table 3). Thus, we conclude that the feed component of the government ESP on aquaculture is effective at encouraging households to use improved feed intensively, thereby, ensuring sustainability once the feed subsidy program is terminated. Consistent with this result is the paper of Liverpool-Tasie (2014) who found evidence of *crowding-in* from fertilizer subsidies on private market participation in Kano, Nigeria. Similarly, in Xu et al.'s (2009) sample-separated analysis, the authors found evidence of *crowding-in* from fertilizer subsidies for households located in areas where private sector activities were low.

Once the decision to purchase improved feed has been made and controlling for endogeneity, we find experience, total agricultural land, price of improved feed, expected price of Tilapia, ownership of a water pump, Western region location, and difficulty in fish marketing to influence the quantity of improved feed purchased by the household.

Household assets such as agricultural land, including crop, livestock, and fish land, increases improved feed demand. Agricultural land can be a source of finance for the purchase of improved feed. Funds from agricultural land could flow from *renting out* lands, as well as crop and animal production returns.

As expected, input and output prices have their *a priori* expected signs, although the price of the substitute feed is statistically insignificant. A rise in the expected price of Tilapia increases the quantity of improved feed purchased significantly, with each Kenya shilling increase in expected Tilapia price raising demand by 0.4 percentage points. The own price of improved feed exerts a negative effect on quantity demanded,

Table 6
Probability of positive demand for improved feed for changes in education, extension, and fish farm size

Years of education	Prob. of positive demand	No. of extension contact(s)	Prob. of positive demand	Farm size	Prob. of positive demand
0	0.246	0	0.391	0.1	0.436
1	0.263	1	0.428	0.2	0.508
2	0.281	2	0.466	0.3	0.581
3	0.299	3	0.505	0.4	0.652
4	0.318	4	0.544	0.5	0.718
5	0.337	5	0.582	0.6	0.778
6	0.357	6	0.620	0.7	0.830
7	0.378	7	0.657	0.8	0.873
8	0.399	8	0.693	0.9	0.908
9	0.420	9	0.727	1	0.936
10	0.441	10	0.759	1.1	0.957
11	0.463	11	0.789	1.2	0.972
12	0.485	12	0.817	1.3	0.982

with a one Kshs increase in price reducing the quantity demanded by 2 percentage points, *ceteris paribus*. The implication is that, if improved feed price continues to increase, households will decrease usage and potentially substitute the traditional feed.

Ownership of a water pump increases improved feed use by about 63%. Given that water is the main natural resource in fish farming, having a pump facilitates maintaining required water levels in ponds, notwithstanding fuel cost. In addition, fish generates different kinds of wastes that require occasional draining and cleaning of ponds to maintain productivity. Ownership of pumps by the household may help foster these operations and contribute to intensification of fish production, and consequently, the demand for improved feed.

Although there is no difference in the probability of purchase across regions, demand is high in the Western region. Specifically, a household located in the Western region purchases about 68% more improved feed than their counterparts in the Rift Valley region, *ceteris paribus*. This might be attributed to the intensive nature of aquaculture operations in the Western region.

5.3. Post-estimation analysis

Once the effect of the subsidy has been controlled for, we further examine the extent to which some key policy variables impact the propensity of the household to demand positive quantities of the technology. Table 6 presents the impact of education, extension contact, and fish farm size on the probability of demanding positive quantities of improved feed. A household head with no education has about 24% lower probability of positive demand than one with 12 years of education. The implication is that government programs that improve education and other knowledge attainment at higher levels are vital for encouraging fish farmers to adopt improved feed.[7]

The effect of fish farm size indicates that households operating one acre of fish farm have about 50% higher probability of purchasing improved feed than those with 0.1 acres. The government's ESP on aquaculture with pond construction as one of the critical components should be seen as an instrument for improved feed demand.

Moreover, households that receive 10 extension contacts per year have about a 76% likelihood of purchasing strictly positive quantities of the technology. Policy options that heighten regular farmer–extension interaction appear to be promising. This suggests providing fisheries extension officers with adequate resources to frequently contact fish farmers may increase adoption of improved feed. Strengthening rural organizations (fish farmer organizations) with active involvement of fisheries extension officers is also recommended. One possible strategy would be to encourage fisheries extension officers to participate in the leadership of these organizations. This option would not only increase agent/farmer interaction, but also obtain feedback from farmers to guide policy formulation in the sector.

6. Concluding remarks and policy implications

This article contributes to the limited empirical literature on the impact of agricultural input subsidy programs on input demand in Africa for aquaculture. Specifically, this article examines the determinants of improved fish feed demand in the presence of a government subsidy program in Kenya, focusing on the Western and Rift Valley regions. The government of Kenya implemented an ESP on aquaculture in which feed and other inputs were given to participating households. The distribution of the feed subsidy was not random, but based on unobservable factors. The nonrandom distribution of the subsidized feed has the potential of causing endogeneity in a household's structural demand model for improved feed. The analysis reported here corrects for this endogeneity using the CF approach, driven by the number of years that the head has resided in the current community as an IV. A corner solution lognormal DH model that considers zeros as optimal choices by the household in addition to allowing for the decision to purchase and the quantity purchased to be determined by different factors is employed. Data for the analysis come from a 2014 survey of fish farming households in the Western and Rift Valley regions of Kenya, allowing us to reference all variables (including the subsidized feed) to the 2013 production year. The findings in this article should be interpreted in the context of improved feed market participation and intensity thereof in the Western and Rift Valley regions of Kenya.

The analysis of the determinants of subsidized feed acquisition indicates that households whose heads have spent more

[7] Note that education is one of the key components of the Kenya government's ESP. Thus, the educational program will have a positive spillover effect on aquaculture operations; it should increase demand for improved feed.

years in school, operate large fish farms, have large household size, and have lived in the current community for a longer time receive more subsidized feed from the government.

There was evidence that subsidized feed decreases the propensity of households to purchase improved feed commercially. However, for households that did purchase improved feed, each additional kilogram of government subsidized feed allocated increases the quantity purchased by about 0.90 percentage points. Since improved feed has not been available to farmers for long, the subsidy program may serve to create awareness and encourage households to adopt the technology as well as increasing the quantity purchased. The subsidy program should also be seen as connecting fish farming households to improved feed technology in Kenya.

Furthermore, demand for improved feed is explained by a number of demand and supply factors. The demand side factors include experience, fish farm size, and the geographic location of the household. On the supply side, household ownership of a pump, and Tilapia and improved feed prices influence demand for improved fish feed in the study regions.

One policy implication might be to create market opportunities for households to sell farmed fish at reasonable prices in order to enhance their demand for the technology. Given that most improved feeds and raw materials are imported, policies that reduce the price of commercially formulated pelleted floating feed (improved feed) might be necessary to increase usage. Reducing tariffs on imported fish feeds and feed production inputs is recommended. Fisheries extension officers should be allocated adequate resources to facilitate their regular interaction with households as this has the potential of raising households' interests in the technology. More research is necessary, however, to determine whether the establishment of improved feed production centers close to fish farming sites increases demand. Finally, a study that looks at the impact of the subsidy program on improved feed market participation in the whole of Kenya and over an extended time period is suggested.

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